SAVEZ INŽENJERA I TEHNIČARA TEKSTILACA SRBIJE
UNION OF TEXTILE ENGINEERS AND TECHNICIANS OF SERBIA

tekstilna industrija

1868 - 2017

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SADRŽAJ

U FINANSIRANJU ČASOPISA UČESTVOVALO MINISTARSTVO PROSVETE, NAUKE I TEHNOLOŠKOG RAZVOJA REPUBLIKE SRBIJE

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REČ UREDNIKA

Tekstilnu industriju karakteriše česta promena modnih tendencija, velika ponuda na globalnom i nacionalnom tržištu, ali ne i toliko velika tražnja. U takvim uslovima, u tekstilnom sektoru opstaju oni koji su u stanju da odgovore na zahteve potrošača. Proizvođači tekstila i odeće zato moraju da imaju osposobljenje i kompetentne zaposlene kako bi mogli da daju adekvatne i brze odgovore u zahtevima sa tržišta. Kao i u svakom razvojnom procesu, ključnu ulogu nose ljudski resursi, te oblast razvoja ljudskih resursa dobija prioritet kada je reč o proizvodnji tekstila i odeće.

U procesu proizvodnje tekstila i odeće, specifičnost je u tome što se mora objediniti sadejstvo umetnika i lica tehničkog profila. Zbog toga ljudski resursi predstavljaju komparativnu prednost svake organizacije tesktilne industrije koja pretenduje na ozbiljan nastup na domaćem ili na međunarodnom tržištu. Ljudski resursi treba da budu organizovani tako da oni stvaraju konkurentsku prednost svojoj organizaciji.

Posebno menadžeri, dizajneri i tekstilni inženjeri koji učestvuju u stvaranju odevnog predmeta moraju posedovati potrebna znanja, veštine i kompetencije koje će im pomoći da brzo reaguju na nastale promene u organizaciji kako bi pravovremenim odlukama obavili postavljene zadatke. Zbog toga je značajno da ljudski resursi u tekstilnoj industriji poseduju samopouzdanje, sposobnost brzog rešavanja problema, znanja i veštine u postavljanju međuljudskih odnosa i svest o ličnim prednostima i manama, zatim moraju imati dar i posedovati kreativnost, iskustva za sintezu mnoštva informacija da bi stvorili odevni proizvod kakav potrošači traže. Razvojem ljudskih resursa sa kombinacijom ovih komponenti kompetentnosti mogu dati rezultate koji se očekuju u uslovima sve većih zahteva tržišta odevnih predmeta.

Prof. dr Snežana Urošević

Naučni i stručni časopis „Tekstilna industrija" u izdanju Saveza inženjera i tehničara tekstilaca Srbije već 63 godine objavljuje naučne i stručne radove, pruža raznovrsne informacije i obaveštenja zaposlenima u tekstilnoj industriji, te na svojstven način daje doprinos očuvanju i razvoju tekstilne industrije u Srbiji, ali i u svetu.

Koristim priliku da Vam se kao glavni i odgovorni urednik obratim i da Vam predložim saradnju i pozovem da pošaljete Vaše naučne ili stručne radove da ih publikujemo u našem časopisu, da reklamirate svoju organizaciju ili svoje proizvode na stranicama časopisa. Takođe, možete da se preplatite na časopis koji izlazi četiri puta godišnje.

Glavni i odgovorni urednik

Prof. dr Snežana Urošević

DESIGN AND CONSTRUCTION OF ADVANCED MODEL OF PROTECTIVE CLOTHES

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Abstract: *The process of designing advanced protective clothes is a lengthy process that is based on research of the model improvement of the protective vests in the Republic of Macedonia. In this paper the main characteristics of the fabric covering material are presented as well as the solution for the model design and construction elements for their final preparation. Based on analyses of different design possibilities of the advanced model, the functional model of protective vest is prepared which the soldier can rapidly and easily remove from his body. The designed model has possibilities for adding soft and hard protective material and it can provide higher level of ballistic protection. Also, the designed model has a modern look in line with functionality and it can be adopted with an appropriate and required level of protection. This advanced model design will completely satisfy the needs of modern soldiers.*

Key words: protective clothes, design, fabric, construction

DIZAJN I KONSTRUKCIJA NAPREDNOG MODELA ZAŠTITNE ODEĆE

Apstrakt: *Proces izrade savremene zaštitne odeće je dugotrajan proces koji se zasniva na istraživanju unapređenja modela zaštitnog prsluka (pancira) u Republici Makedoniji. U ovom radu su predstavljene osnovne karakteristike tkanina, kao i rešenje za dizajn modela i konstruktivnih elemenata za njihovu finalnu pripremu. Na osnovu analiza različitih mogućnosti dizajna naprednog modela, izrađen je funkcionalni model zaštitnog prsluka koji vojnik može brzo i lako da skine. Izrađen model ima mogućnost dodavanja mekog i čvrstog zaštitnog materijala i može dostići viši nivo balističke zaštite. Takođe, izrađen model ima moderan izgled koji je u skladu sa funkcionalnošću i može se primeniti uz odgovarajući i neophodan nivo zaštite. Novi dizajn u potpunosti će zadovoljiti potrebe savremenih vojnika.*

Ključne reči: zaštitna odeća, dizajn, tkanina, konstrukcija

1. INTRODUCTION

Clothing has been used for protection since the beginning of time, shielding the human body from physical, social, emotional, and spiritual threats, real and imagined. Today, the term, protective clothing is generally used to denote apparel and apparel accessories that focus on physical protection for the body [1].

The process of designing specific protective clothes includes the entire design activity for the development of new products with high technological content from the initial idea and first project concept, to the design analysis, considering new materials and different types of research during the steps of designing, prototyping and final manufacturing. Firstly, we should find the roots and the first forms and materials which were used for protective clothes protection, and then to present the new contemporary design of protective soldier clothes [2]. In the past, different civilizations and cultures around the world used the protective clothing that

was made from natural raw materials. The oldest data indicate that the first type of protective clothing was made of leather, and was found in Europe and East Asia. The first known armor, worn by the Egyptians in 1,500 B.C.E., consisted of an unwieldy shirt-like garment to which overlapping bronze plates were sewn [3]. In the eighth century B.C.E., the Greeks made improvements on this garment by shaping metal plates to each body part. With the development of chain mail by the Celts in the third century B.C.E., a warrior's ability to function in battle was significantly improved. Mail was lighter than earlier armor and flexed with every body movement. Since it provided protection from arrows and knives and other weapons of the times, chain mail remained as the primary protective material used in battle for many centuries [4].

The first commercial protective vest was made of silk fiber in the late 1800's. One of the first recorded descriptions of soft armor use was found in medieval Japan, and the armor was made of silk [5]. With the growth and progress of civilization, the soldiers used wooden shields and later they protected their body chest from injures with vest made of metal. With the invention of artificial fibers the perfect base to make the protective clothes with a higher level of protection was created, and the range of design became wider. Soldiers in World War I in the 1920s continued to wear garments to which metal plates were attached. Metal and ceramic coverings provided protection for airmen during World War II, but these were much too heavy for the ground soldier [6]. In the mid-1960s, when Kevlar aramid fibers were patented and made into fabrics, it finally became possible to design relatively thin, lightweight, flexible shields for bullets and explosive fragments. These designs made it possible for armor to function covertly as well. The technological advances during the 20-th century made the protective clothes that have modular design, consisted of a basic part and accessories for extra protection that can be attached on it. The vests are made of light waterproof materials, resistant to heat and chemicals, so the soldiers can walk and run easily [7].

2. ANALYSIS ABOUT THE PROTECTIVE CLOTHES IN R. MACEDONIA, ACCORDING TO THE NEED OF NEW DESIGN OF PROTECTIVE VEST

The advanced generation of the protective clothing can provide different levels of protection, absorbing the low and medium levels of energy. Protective clothes which protect from guns in its structure contain heavy materials as ceramics and metals. The construction form of modern body armor allows easy adaptability to the human body. Protective clothing should not adversely affect the health of the soldiers and materials used for protective clothing should be chemically suitable, and should not release substances that are toxic or harmful in any other way. The material used for protective clothes should not be degraded to release substances that are carcinogenic and allergenic.

The new design of protective vest should have the following characteristics (features):

- Correct position of clothing to the user's body, protective clothes should stay in place within the stipulated period.
- Protective clothes must be correctly adjusted to the morphology of the soldier.
- The protective clothes should be flexible in order to allow the soldier to move freely but at the same time to be protective.
- The protective clothes should be easily removed in situation when it is needed.

Also, the protective clothes design should be resistant to water vapor, air, chemicals and heat, and at the same time it should minimize discomfort and heat pressure.

In the moments when seconds are critical to saving lives, the functionality of the protective clothing plays the main role. If the soldier can rapidly and easily remove vest from the body he can save his life and lives of other soldiers.

The protection material for the design of protective vest should be made of the following fibers:

Dyneema® which are super-strong fibers, made from Ultra High Molecular Weight Polyethylene (UHMWPE) and offers maximum strength with minimum weight. This makes number of possible applications. It advantages are:

- up to 15 times stronger than steel (weight for weight basis),
- up to 40% stronger than aramids (weight for weight basis).

UHMWPE fibers are applicable in construction of protective clothes because of the excellent resistance to bases and acidic chemicals, the excellent compressive strength and excellent water resistance.

High performance inorganic fibers - carbon, glass and ceramic, have high mechanical properties, electrical and thermal conductive highly resistant. They are used as reinforcements for composites and also for electromagnetic and electrostatic protection.

Polyamide (nylon fibers) are used widely in the industry for protective clothes. They are fibers with excellent elasticity and agility in deformations.

Nomex® fibers are used in numerous applications for the preparation of the outer layer of protective clothes. They have good dimension stability and excellent heat resistance. They are widely used in protective manufacture clothing. The materials obtained from this fiber have low levels of flammability and are resistant to melting at high temperatures.

Besides the protective function, the clothes should be comfortable to conserve energy balance within the limits of tolerance for warmth or coldness of the body.

Modern lifestyles and advances in technology impose the need for the application and development of new contemporary designs of body armor for protective clothes. The new design should make the product more competitive, and comparable to many products in Europe and beyond, taking into account the preservation of price/performance. The design of the currently existing body armor produced in R. Macedonia is quite simple, with classic shape and minimalistic design.

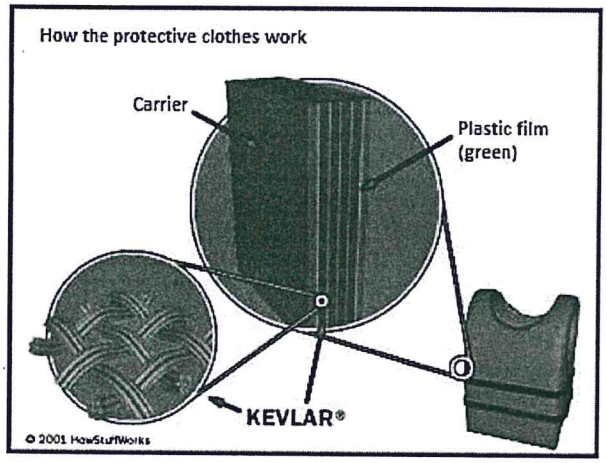


Figure 1. - *Structure of protective clothes [8]*

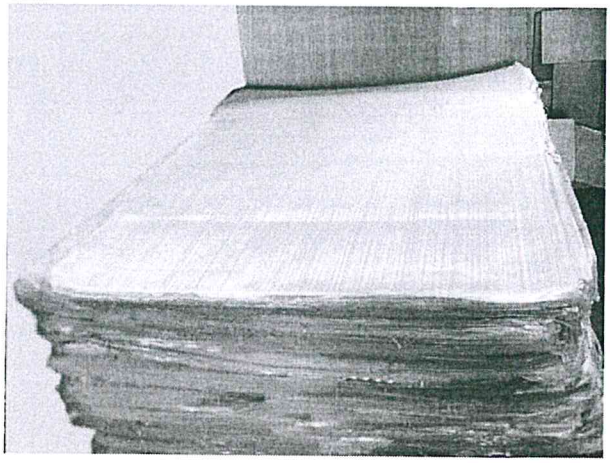
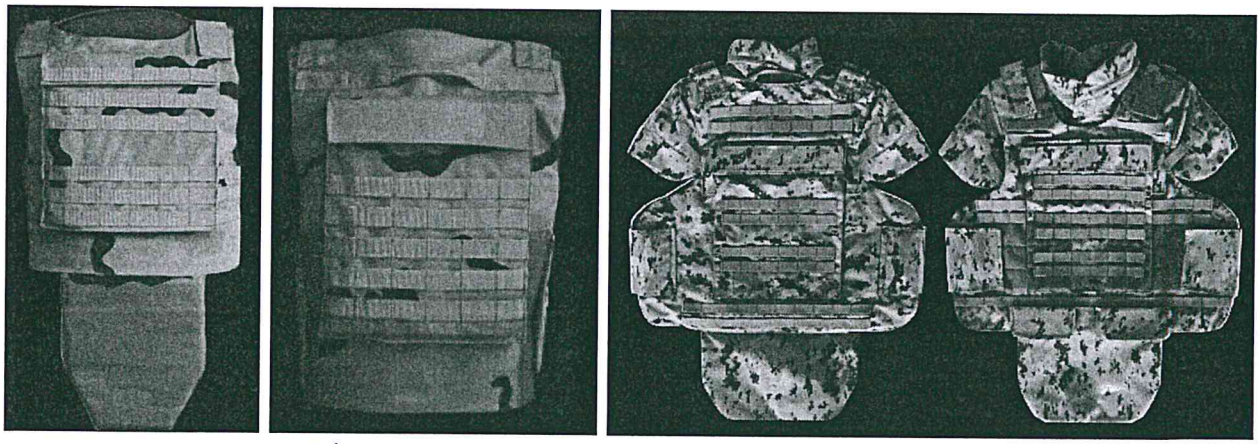


Figure 2. - *Dyneema® protective layers [9]*



vest 1 *vest 2*

Figure 3. - *Protective vest1 and vest 2 front and rear part [10]*

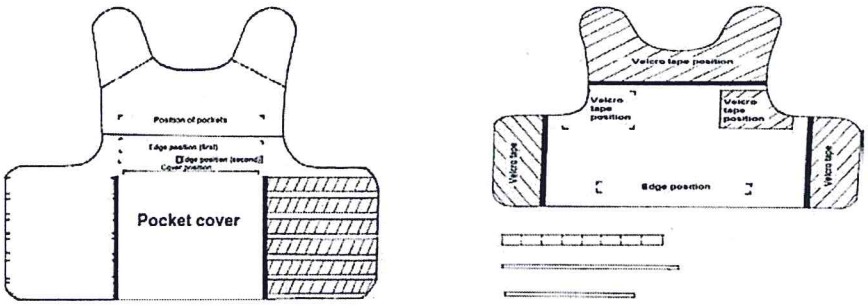
Table 1. *Main characteristics of protective vests (model1 and model 2) [10]*

	Level of protection	Outer Fabric	Balistic Material	Weight (kg)	Guarantee (Years)	Color
Model 1	IIIA (acc.NIJ 0101.04)	Cordura (waterproof)	UHMW PE UD/Aramide	2,7	5	camouflage
Model 2	IIIA (acc.NIJ 0101.04)	Cordura (waterproof)	UHMW PE UD/Aramide	4,5	5	Camouflage design upon request

3. THE EXPERIMENTAL PART

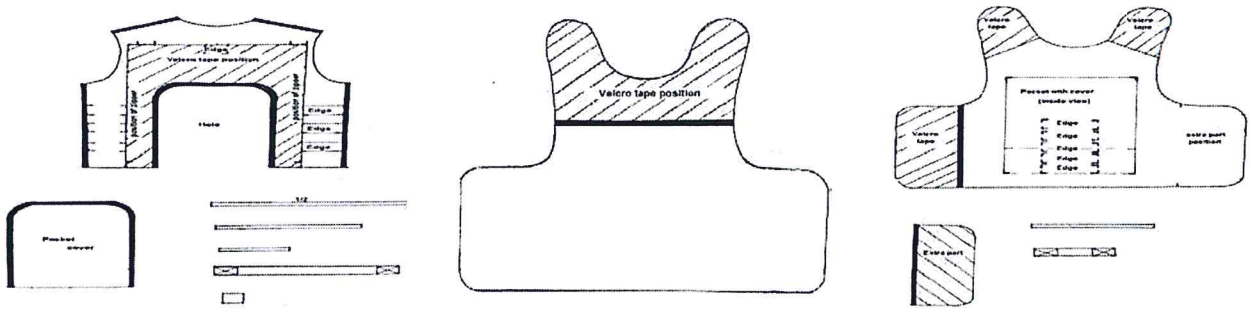
The experimental section provides design and constructional solution for the protective vest that was a requirement of the international market. Experience shows that military clothing should be blend of design and functionality. This research was aimed at discovering the relationship between technology and art, the point at which they join together and become one, resulting in designer solution that fully meets the requirements of advanced military. The characteristics of used covering material are presented in Table 2. For the protective clothes two main characteristics are very important: weight of the body vest and the time that the soldier needs to remove the vest from his body. They are serious problems especially in situations when mobility is reduced, or the soldier is injured. Great armor weight which includes a weight of protective plates and a large number of accessories creates difficulties in the evacuation of troops from attack. In this paper, design and construction of protective vest is made through the use of cables which are inserted into separate partitions, so the soldier can simply remove the vest from his body in a few seconds. The main construction parts of the design solution for the front and back, inner and external parts are presented on the figures 4 and 5. As can be seen, the model has layers for the soft protective material and for the cables for easily vest removal, as well as pockets in the front and back external parts for ballistic (inserts) plate.

At the same time, the vest has a new futuristic design which corresponds to the needs of the soldier in 21-st century. The model was made of polyamide material in black color (cordura) as a covering material with excellent strength, high resistance to abrasion, sunlight and low affinity for water (Table 2). Ballistic protection can be achieved with material made of UHMWPE fibers or other materials according to the needs of the users. The layers of material will be determined according to NIJ standard for the appropriate protection. Analysis of the ballistic material is not given in this paper, because the main point was only the design and construction elements of the protective vest. Accessories for the preparation of the protective vest are a combination of black and silver parts that captures the look of a soldier in the medieval period and at the same time follows the trend of 21-st century. The new model of protective vest is a perfect combination of past and present and should represent the future and progress of military protective clothing.



front look *inward front look*

Figure 4. - *The main constructive parts of the front side of protective vest*



back central part *inner back part* *back external part*

Figure 5. -*The main constructive parts of the back side of protective vest*

Table 2. *Technical characteristic of used outer material for the new model of protective vest*

No.	Parameters	Technical characteristics (material)
1.	Color	Black
2.	Type of material	Fabric
3.	Composition	100% PA
4.	Mass per unit area	185 (g/m²)
5.	Tensile elongation (daN)	wrap min 90 weft min 70
6.	Tensile strength (daN)	wrap min 5 weft min 5
7.	Shrink at washing 40° C (%)	Width ≤ 3 Length ≤ 3
8.	Shrink at chemical cleaning (%)	Width ≤ 3 Length ≤ 3
9.	Consistency of color - the mark	- Light 4 - Dry / wet 4/3 - Pot 4 - Washing 40° C 4 - Dry cleaning 4
10.	Water Resistance (method C)	≥ 80

4. RESULTS AND DISCUSSION

Based on the construction analysis and prepared construction parts, the model of protective vest was sewn (prepared). All sewn parts of the protective vest are presented, including removable sleeves, collar, pockets and cables for easily removing the vest from soldier's body (fig.6 - 8). Also, the final look is presented on figure 9. The purpose of layering of the protective vest is to create a dynamic system, which will promote the diffusion of liquid away from the skin, prevent chilling and maintain comfort. The base layer is worn directly next to the body. It is primarily used to keep the skin dry and at a regular temperature. This is largely achieved through the composition and structure of the fabric selected. However, all of our base layers are also designed to maintain freedom of movement. The mid layer is added to increase insulation and maintain body heat. This must remain dry and therefore polyester fabrics, which are light weight, resistant to compression and breathable are considered optimum. The outer shell is used to protect the underlying layers from environmental moisture and wind. This is principally accomplished with high performance fabrics, which also promote water vapour transfer out of the clothing system.

Today the design is deeply involved into all spheres of life, and this model shows that design takes his part in the appearance of protective clothing.

Design solution presented in this paper has the following advantages of protective clothing:

- design of the covering material with more layers,
- easy removal of the soldier's body,
- easy to carry,
- high degree of protection,
- modular components that can be easily remove from the body with velcro tapes,
- collar, mobile-sleeved,
- increased number of pockets for functional and safety purposes,
- cables for instantly removing from the body,
- hidden internal compartments for soft and hard ballistic protection,
- the use of modern materials, modern looks in line with functionality and high quality.

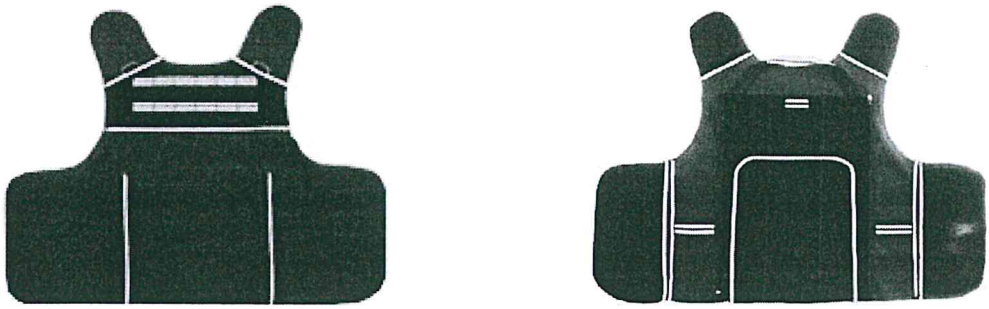


Figure 6. - *Front and rear look of protective vest*

Fig 7. *Features an open rear protective vest*

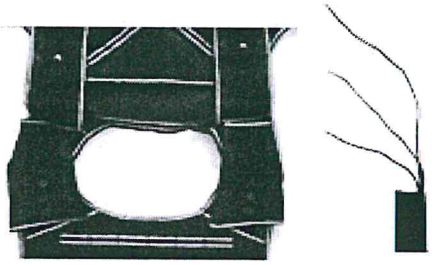


Fig 8. *Arms cases and removable cable case*

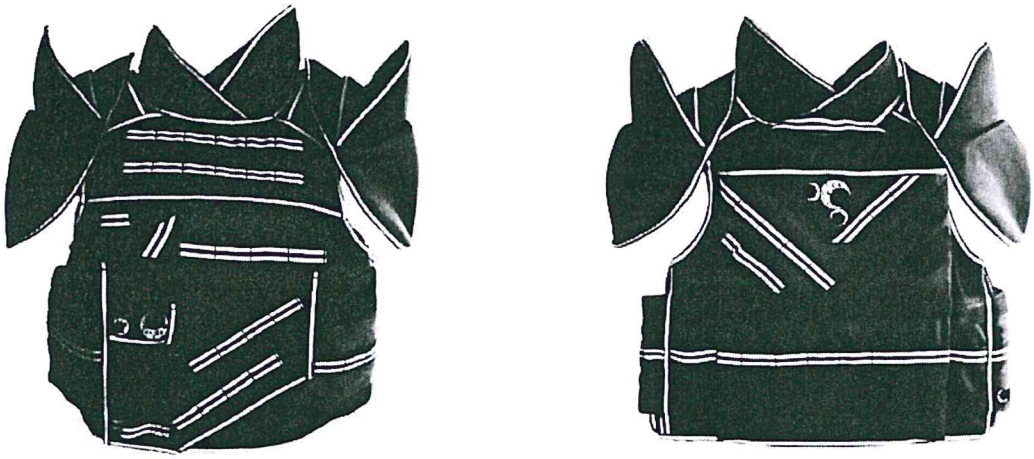


Figure 9. - *Front and rear look of prepared model of protective vest*

By modeling the basic shape of the simple design of protective vest and with the changes of the outer look that was made, the modern design of protective clothes is implemented. That creates a good base for further ideas in the field of protective clothes design.

5. CONCLUSION

In this paper an analysis of design of protective clothing was made, and the requirements for a new design were analyzed. Also, one of the possible solutions for design of protective clothing is presented. Based on all inputs for designing of new model, the functional protective vest was prepared. The designed protective vest contain more layers and allows

installation of suitable materials for soft and hard protection depending on the user's demands and it is easily removable vest. In this paper it is given solution only for the design of protective clothing. Analysis for the soft and hard protection as well as full functionality of protective clothing will be a goal for our future research.

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